CHENEGA ISLAND MANGANESE OCCURRENCE

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CONTENTS

ILLUSTRATIONS

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

mm	millimeter
cm	centimeter
m	meter
ft	foot
ft3/st	cubic foot per short ton
g	gram
in	inch
kg	kilogram
lb	pound
mi	mile
pct	percent
ppm	parts per million
ppb	parts per billion
st	short ton
yd3	cubic yard

ABSTRACT

A geologic and geophysical investigation was performed on a manganiferous-iron occurrence on the north shore of Chenega Island, Prince William Sound (AK). The purpose of the investigation was to delineate the size of the occurrence and to define the controls on mineralization.

A tabular manganiferous horizon composed primarily of magnetite, rhodonite, pyroxmangite, rhodochrosite, and iron sulfides occurs within volcano-sedimentary rocks of the Eocene Orca Group. The horizon ranges in width from 3 to 7 ft and, through the results of detailed mapping and a magnetometer survey, an inferred strike length of 1150 ft.

Characteristics of the occurrence classifies it in the siliceous-greenstone group of volcanogenic manganese deposits. In this group, spilitization or "seafloor metamorphism" appears to be a significant alteration event in the ore forming process through leaching and subsequent precipitation Mn, Fe, Si, and Ca. Evidence supportive of this process in shown by paragenetic relationships of the ore minerals, alteration patterns, and the presence of a low grade hydrous metamorphic mineral assemblage.

The horizon contains indicated resources that range between approximately 20,000 and 40,000 st of Mn within 115,000-230,000 st of rock respectively, at a selected grade of 17 pct Mn. The tonnage estimates are comparable to volcanogenic deposits worldwide, however, grade values are significantly low.

INTRODUCTION

In conjunction with the Bureau's strategic and critical mineral studies, a manganiferous-iron occurrence was investigated on Chenega Island, southern Alaska. Manganese is a strategic metal that has no satisfactory substitute for it's role in iron and steel metallurgy. The manganese industry is mostly committed to the production and the consumption of ferroalloys for which the United States is foreign dependent.

During a mineral assessment of the Chugach National Forest in 1981, Bureau geologists were following-up an anomalously high copper stream sediment sample on the north shore of Chenega Island and discovered a bold, tabular, manganese-rich outcrop. Kurtak (1)[1] sampled and described the occurrence and recommendations were made for detailed sampling and a ground magnetometer survey.

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[1]Underlined numbers in parentheses refer to items in the list of references at the end of this report.

LOCATION, ACCESS, AND LAND STATUS

Chenega Island is located in the southwestern portion of the Seward B-3 quadrangle immediately west of Knight Island along the westcentral shore of Prince William Sound, southcentral Alaska (figure 1). Rock exposures are best along beach cliffs and the upper elevations of the Island. The lower elevations consist of low, heavily vegetated hills with abundant ponds and lakes.

Access to the island was achieved by small aircraft, equipped with floats, from Seward, Alaska. Several sheltered coves and bays on the island provide safe landing. Inflatable canoes proved effective in exploring the shoreline in the vicinity of the Mn-occurrence and for performing an offshore magnetic survey.

Chenega Island is among the holdings of the Chenega Village Corporation, and the subsurface estate is owned by the Chugach Alaska Corporation, Anchorage (AK), a native regional corporation.

ACKNOWLEDGMENTS

The Bureau would like to acknowledge the Chugach Alaska Corporation for granting access and permission to perform our studies and for their continued cooperation. We would also like to thank Linda Reinink-Smith for her capable assistance in the field.

PREVIOUS STUDIES

Grant and Higgins (2) and Moffit (3) performed regional geologic mapping in the Prince William Sound region and include descriptions of the rocks on and near Chenega Island. More recent studies by Tysdal and Case (4) include geologic mapping of the Seward quadrangle at 1:250,000 scale. Case and others (5)

Figure 1. - Location map

provide geologic interpretation of regional aeromagnetic data and indicate that the largest anomaly in the region is centered over Chenega Island.

Dumoulin (6) performed petrographic studies including point count analysis on several sandstone samples collected from the Prince William Sound region and included rocks from Chenega Island.

A proprietary report by C.C. Hawley released to the Bureau contains detailed and reconnaissance geologic and ground magnetics information regarding the Mn-occurrence and other areas of the island.

REGIONAL GEOLOGY

The geology of the Kenai Peninsula - Prince William Sound region of Alaska is characterized by broad, arcuate belts of Mesozoic and Cenozoic accretionary rocks. The rocks on Chenega Island occur within the Paleogene Orca Group which is described by Plafker (7) to consist of a thick sequence of complexly deformed and faulted flysch deposits intercalated with mafic volcanic rocks. The Orca Group is separated from the Valdez Group on the north by the Contact Fault System (6). The Valdez Group represents a similar assemblage of Jurassic and Cretaceous age rocks and was originally subdivided based on slight differences in lithology and metamorphic grade (3) yet the distinction on Chenega Island and Bainbridge Island to the south is unclear. Based on petrographic and compositional data Dumoulin (6) states that the Valdez and Orca Groups represent a single, continuous flysch sequence.

The Orca Group has been regionally metamorphosed from laumontite to upper-greenschist facies and has been intruded by intermediate plutons of Eocene age. The plutons have produced local increases in metamorphic grade to the amphibolite and hornblende-hornfels facies (6).

Moffit (3) describes a granitic body a few miles north of Chenega Island, at Granite Bay and Eshamy Bay, as having intricately intruded the slates and graywacke forming pendants and giving the rock a gneiss-like appearance. He further states that due to the close proximity of the granite to the northern shore of Chenega Island, the rocks have experienced local changes in metamorphic grade and structure.

BUREAU OF MINES INVESTIGATION

GEOLOGIC SETTING

The host rocks in the vicinity of the Mn-occurrence consist primarily of intercalated argillite, greenstone (metamorphosed and altered basalt), of the Orca Group. Figure 2 is a geologic and sample location map of the area surrounding the manganese occurrence.

The argillite is very fine-grained and composed of alternating light to dark brown quartzofeldspathic layers ranging in thickness from 1-5 cm and exhibits variable degrees of slaty cleavage (in places phyllitic). A few of the layers are slightly

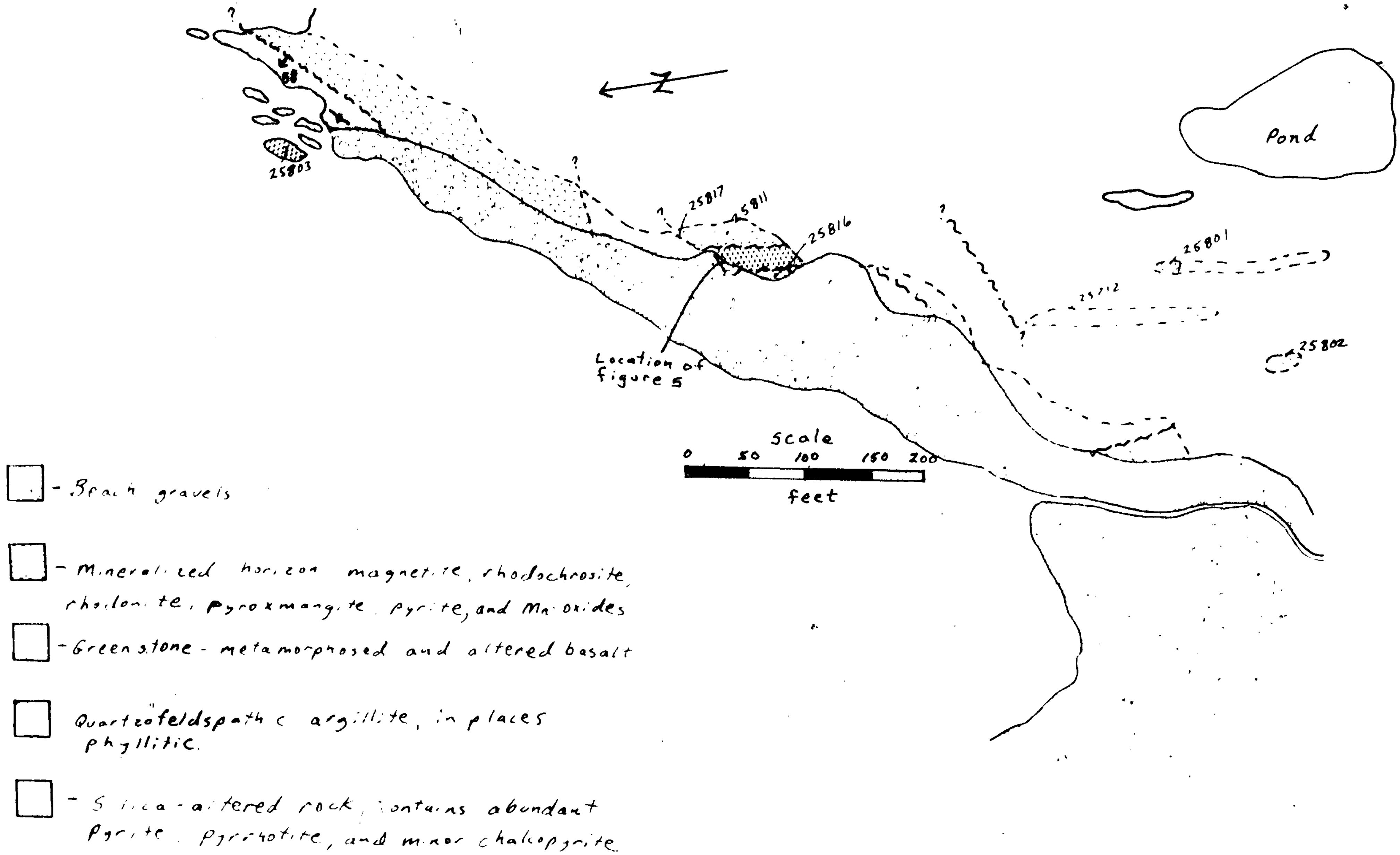

Figure 2.- Geologic and sample location map

Figure 6 is a photomicrograph of a sample collected from the boulders and shows pyrrhotite grains within a quartz matrix.

Magnetite is the most abundant ore mineral and appears to have been the earliest to form. The magnetite is very-fine-grained, anhedral, and contains abundant inclusions of quartz and calcite (Figure 7). Pyrrhotite and chalcopyrite are moderately abundant and occur as grains ranging in size from <0.2mm-1mm and are commonly intergrown. Very-fine-grained pyrite is widely disseminated throughout the samples and is particularly abundant in the boulders that eroded off the beach cliff.

Manganese minerals present include rhodonite ($MnSiO_3$), pyroxmangite ($(Mn,Fe)SiO_3$), and rhodochrosite ($MnCO_3$). Rhodonite occurs as subhedral grains ranging in size from <0.2mm to 1mm and is commonly intergrown with pyroxmangite. Rhodochrosite and calcite (probably manganoan(8)) commonly occur in late stage pods and veinlets as subhedral grains never exceeding 2mm in size. Chalcedony is moderately abundant in the rhodonite-rich samples and occurs as irregular shaped pods and open space fillings. A low grade metamorphic mineral assemblage of epidote + calcite + quartz ± fibrous amphibole ± chlorite is variably present in all of the samples.

Surficial oxidation of the manganiferous horizon has resulted in pervasive black coatings of manganese oxide minerals manganite ($MnO(OH)$), intergrown with psilomelane ($(Ba,Mn)_3(O,OH)_6Mn_8O_{16}$) and pyrolusite ($MnO_2$). The Mn-oxides penetrate the surface of the outcrop and rubble up to 1 cm in depth.

ROCK SAMPLING

METHODS

Chip and grab samples were collected from the manganese-rich zone, wallrock, and surrounding lithologies for geochemical analyses and petrographic examination. Nine rock samples were sent to a commercial laboratory for preparation and analysis of 42 elements by emission spectrographic techniques. Samples exceptionally high in manganese and iron were reanalyzed by titrametric methods. Two of the samples were further analyzed for all six PGE and gold by neutron activation.

One bulk sample (87 lb) from the mineralized zone was sent to the Bureau of Mines Albany (OR) Research Center for mineralogical characterization and head analyses.

Results of geochemical analyses and descriptions of samples are included in the Appendix.

GEOPHYSICAL SURVEY

GROUND AND MARINE MAGNETOMETER SURVEY

METHODS

A reconnaissance magnetometer survey was performed to determine the magnetic signature and continuity of the manganiferous-iron

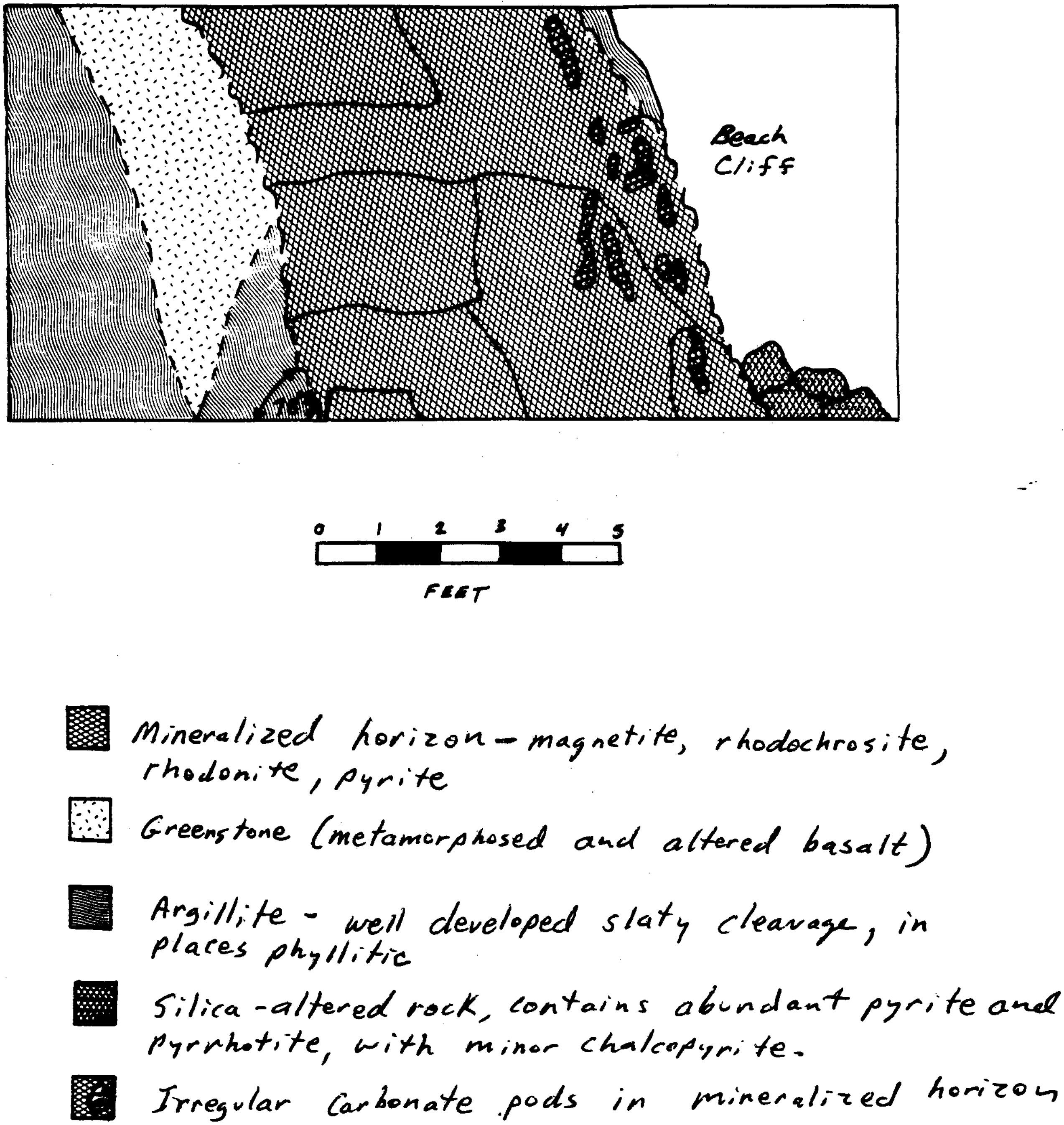

Figure 5. - Detailed sketch map of mineralized beach outcrop.

Figure 4. - View of mineralized offshore shoal with mineralized beach outcrop in background.

calcareous. Judging from the thickness and rhythmic nature to the layering and overall fine grain size, the argillite most likely represents middle to outer submarine-fan deposits.

The greenstone is aphanitic to fine-grained, dark green, and composed primarily of chlorite and trace amounts of subhedral clinopyroxene and sphene. Subhedral, fine-grained epidote is present as late-stage veinlets and crack fillings. Magnetite is abundant (up to 15 pct of the rock) within the chloritic groundmass as very-fine-grained disseminations.

In the vicinity of the mineralized horizon, the greenstone contains discontinuous lenses and layers of fine-grained polygranular quartz. The amount of quartz increases gradationally to nearly 100 pct in rock adjacent to mineralization. Metamorphism has produced 120° grain boundaries among the quartz grains, and calcite and acicular amphibole are present as alteration products. Both the argillite and greenstone contain veinlets (<1 cm) and crack fillings of quartz and calcite and possess variable amounts of limonitic stain. Pillow structures are not present in the immediate vicinity of the Mn-occurrence, however they are apparent in the greenstone on cliff exposures across the inlet to the west.

The attitude of the foliation, apparent bedding, and layering of the rocks is generally ENE with steep westerly dips. Numerous, small, high-angle shear zones and apparent faults cut the section and are defined by pronounced foliation and slickenside surfaces.

MINERAL OCCURRENCES

Mineralization is best exposed along a beach cliff outcrop that consists of a bold, resistant, tabular horizon composed of massive concentrations and irregular segregations of a mixed assemblage of iron and manganese minerals (figure 3). The dimensions of the exposure is 7 ft wide by 55 ft long, by 35 ft high. The strike of the outcrop is north 10° east and it dips steeply to the west at an angle of 78-80°. The mineralized horizon is covered by beach gravels to the north but mineralized offshore shoal exposures indicate a strike length continuation of approximately 400 ft (figure 4). To the south, a similar extension (approximately 300 ft long) under heavy vegetation is inferred to where a mineralized outcrop was uncovered in a pit dug by the author.

Figure 5 is a detailed sketch map across the face of the mineralized beach outcrop. The contacts on each side of the mineralized horizon are intensely sheared as evidenced by well-developed slaty cleavage within argillite and abundant slickenside surfaces within greenstone. The mineralized horizon is composed almost entirely of magnetite and manganese minerals, however abundant irregular pods of carbonate occur along strike in the beach cliff margin of the mineralized horizon. Numerous large boulders of silica-rich rock, that have clearly eroded off the beach cliff, contain abundant pyrrhotite, pyrite, and chalcopyrite and are essentially barren of manganese minerals.

Figure 3. - Views of mineralized beach outcrop.

Figure 6 is a photomicrograph of a sample collected from the boulders and shows pyrrhotite grains within a quartz matrix.

Magnetite is the most abundant ore mineral and appears to have been the earliest to form. The magnetite is very-fine-grained, anhedral, and contains abundant inclusions of quartz and calcite (Figure 7). Pyrrhotite and chalcopyrite are moderately abundant and occur as grains ranging in size from <0.2mm-1mm and are commonly intergrown. Very-fine-grained pyrite is widely disseminated throughout the samples and is particularly abundant in the boulders that eroded off the beach cliff.

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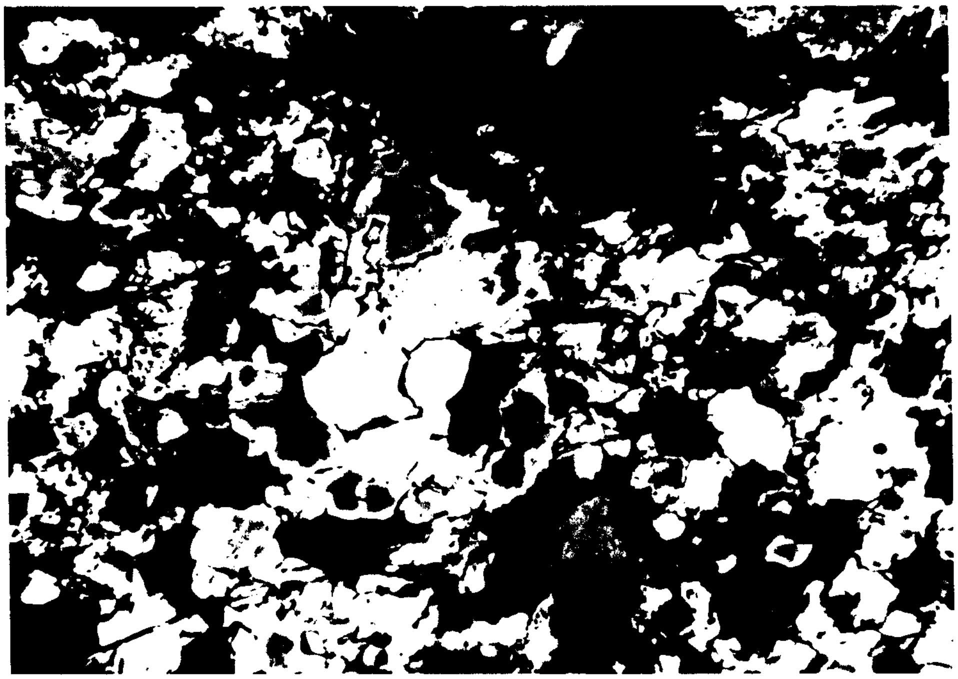

Figure 6. - Photomicrograph of silica-altered zone. Opaque mineral is pyrrhotite. Length of view is 6.0 mm, crossed polars.

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Figure 7. - Photomicrograph of magnetite (opaque mineral) with abundant inclusions of quartz and calcite. Length of view is 1.5 mm, crossed polars.

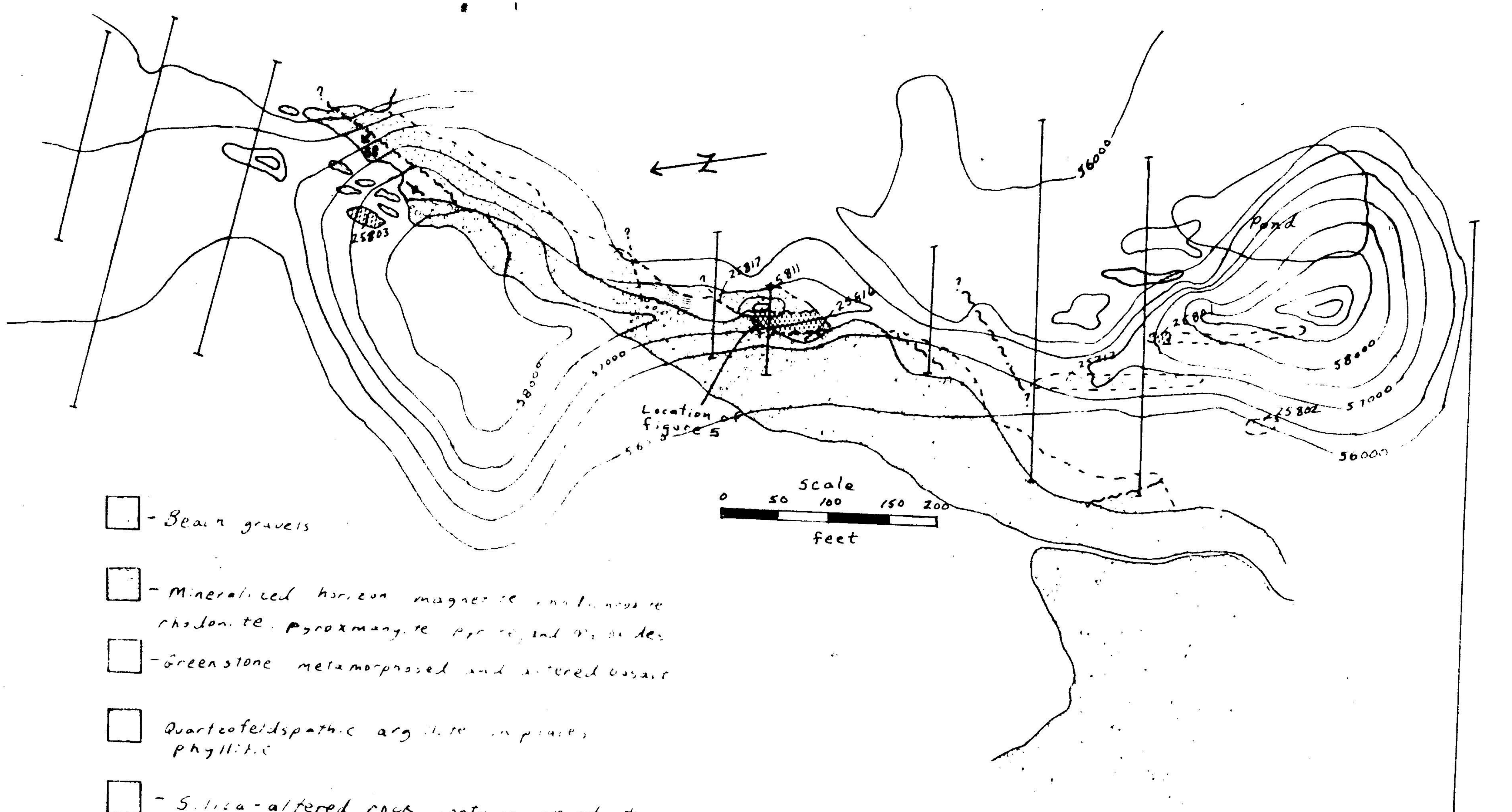

Figure 8. - Magnetic Contour map (500 gamma contour interval)

occurrence, both onshore and offshore. Onshore lines were surveyed with brunton and tape and offshore lines were approximated using the shoreline and shoals as a reference. The magnetic measurements were made with a Geometrics[2] proton procession magnetometer. Readings were taken at 10 ft intervals along east-west striking lines with the sensor detached and staff-mounted, therefore, providing 1-gamma accuracy. No base stations were used, however, several stations were reoccupied and no significant variations were encountered. The locations of the magnetometer traverse lines are shown in figure 8.

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[2]Use of trade names does not imply endorsement by the Bureau of Mines.

RESULTS

Because of the abundance of magnetite, the mineralized horizon possesses a strong magnetic signature and the magnetometer survey proved to be an effective method in tracing the Mn-occurrence both on and offshore. Magnetic readings from the mineralized horizon were generally 2000-4000 gammas higher than the country rock, mostly greenstone and argillite. Figure 8 is a magnetic contour map depicting the results of the magnetometer survey. The contours broadly define the linear trend to the mineralization, however, detailed inspection of the data suggest that the horizon is apparently faulted, being locally offset both right- and left-laterally and in places magnetic anomalies closely parallel one another.

VLF SURVEY

A reconnaissance VLF survey was performed and proved unsuccessful as no identifiable conductor was detected.

DISCUSSION

A volcanogenic origin is ascribed for the manganiferous-iron occurrence on Chenega Island. Subsequent metamorphism has obscured the original character of the deposit.

Roy (9) classified volcanogenic manganese deposits based on lithologic association; the subdivision that is most pertinent to the Chenega Island occurrence is that of the greenstone-siliceous group. Examples of this group include Eocene deposits of the Olympic Peninsula, Washington, and manganiferous-iron deposits on the Pacific side of the Japanese Islands (9). A newly discovered manganese deposit on Hinchinbrook Island, Alaska (10) is interpreted to be of volcanogenic origin and is similar in age and geologic setting to the Chenega Island occurrence.

The mechanism responsible for concentrating manganese and iron in the greenstone-siliceous group of deposits is spilitization, a form of low grade "seafloor metamorphism" induced by heat and fluids retained in submarine basalt flows and the pressure of the overlying water column (11). During spilitization manganese, iron and silica are leached from the basalts and preferentially precipitated, depending on pH and oxidizing conditions of seawater and the receptiveness or neutralizing properties of the material at the sea water-sediment interface (12). Krauskopf (12) perceived that precipitation would commence with iron oxides being distributed throughout the basalts and associated sediments thereby concentrating manganese in layers and horizons between the flows. Furthermore, the fact that this class of volcanogenic deposits are commonly associated with siliceous and carbonate rocks ("chert and limestone") may indicate that Ca and Si are also involved in the leaching and precipitation process (12).

The above process is evident in the paragenetic sequence of minerals and lithologies associated with mineralization at the Chenega Island occurrence. Iron oxide in the form of magnetite was the first ore mineral to form and is abundantly dispersed throughout the lava and the argillite. Manganese mineralization followed, concentrating in layers. The irregular carbonate pods and siliceous rocks associated with the mineralization, along with the low grade hydrous metamorphic mineral assemblage of epidote + quartz + calcite + fibrous amphibole ± chlorite ± chalcedony are evidence supportive of spilitization.

An encouraging aspect that pertains to deposits of this type is their laterally extensive distribution. Over 150 volcanogenic manganese deposits occur along a 200 km trend in Middle Eocene volcano-sedimentary sequence similar to the Orca Group on the Olympic Peninsula, Washington (9) and similarly extensive trends have been defined in Cuba, Japan , and numerous locations in U.S.S.R. Features of the Hinchinbrook Island occurrence, in Prince William Sound, including age, tectonic setting, metamorphism, and some aspects of the mineralogy are characteristic of the Chenega Island occurrence and is suggestive of a trend worthy of investigation.

A leaching and precipitation mechanism similar to spilitization has been suggested for the origin of manganiferous ores (umbers) and iron-rich sediments (ochres) within the Troodos massif, Cyprus (13). During the later stages of ocean-floor volcanism seawater permeates the lava pile and leaches Fe, Mn, and other elements. Upon reaction with oxygenated seawater, rapid precipitation and partitioning of phases occur at the seawater-sediment interface (13). Massive sulfide mineralization similar to that found at Cyprus is envisioned for deposits on Knight Island, immediately east of Chenega Island. Two major deposits and numerous small occurrences of Cyprus-type massive sulfides occur within volcano-sedimentary rocks of the Orca Group and it seems plausible that the mineralization on Chenega Island is correlative(14).

RESOURCES

Resource classifications are made according to guidelines set forth in the joint U.S. Bureau of Mines - U.S. Geological Survey publication, "Principles of a Resource/Reserve Classification For Minerals" (16). "Indicated resources" are calculated for the

Chenega Island occurrence based on the assumption that the grade of the main mineralized horizon is consistent over a strike length of 1150 feet. This strike length is inferred by the presence of mineralized outcrops along strike and the results of the magnetometer survey.

Assuming mineralization continues for one-quarter to one-half the strike length at depth, maintains a selected width of 3.5 ft at a selected grade of 17 pct Mn, and at an estimated tonnage factor of 10 ft^3/st an indicated resource range of approximately: 1) 40,000 st Mn within 193,000 st of rock for a depth estimate of one-half the strike length., 2) 20,000 st of Mn within 96,500 st of rock for a depth estimated of one-quarter strike length.

Grade and tonnage models for volcanic manganese deposits worldwide reveal relatively small tonnage potential, however high grade Mn (50% probability of 47,000 tons at 42% Mn)(16)(figure 9). The above tonnage calculation for the Chenega Island occurrence plots between the 50 and 60th percentile ranges on figure 9 and appear reasonable, however, grade comparisons are significantly lower than worldwide deposits.

SUMMARY AND RECOMMENDATIONS

A volcanogenic manganiferous-iron occurrence on the north shore of Chenega Island occurs within volcano-sedimentary rocks of the Eocene Orca Group. A bold, tabular outcrop composed primarily of magnetite, rhodonite, pyroxmangite, rhodochrosite, and iron sulfides strikes for 55 ft along the beach and is inferred, through detailed mapping and results of a magnetometer survey, to persist for 1150 ft along strike. Surficial oxidation of the outcrop has resulted in pervasive coating of manganese oxides.

Characteristics of the occurrence classifies it in the siliceous-greenstone group of volcanogenic manganese deposits (9). In this group, spilitization or "seafloor metamorphism" appears to be a significant alteration event in the ore forming process through leaching and subsequent precipitation Mn, Fe, Si, and Ca. Evidence supportive of this process in shown by paragenetic relationships of the ore minerals, alteration patterns, and the presence of a low grade hydrous metamorphic mineral assemblage

Using a selected grade of 17 pct Mn the occurrence contains indicated resources that range between 16,500 and 33,000 st of Mn within 96,000-193,000 st of rock respectively. The tonnage estimates are comparable to volcanogenic deposits worldwide, however, grade values are significantly low.

The Chenega Island occurrence resembles other volcanogenic manganese deposits worldwide. A characteristics of these deposits and the processes that form them is that they are typically lateraly extensive and occur in trends. This observation suggests that the Prince William Sound region, in the vicinity of Chenega Island, an area worthy of investigation in effort to locate manganese resources.

It is recommended that work in Prince William Sound be continued, starting with a detailed ground and marine

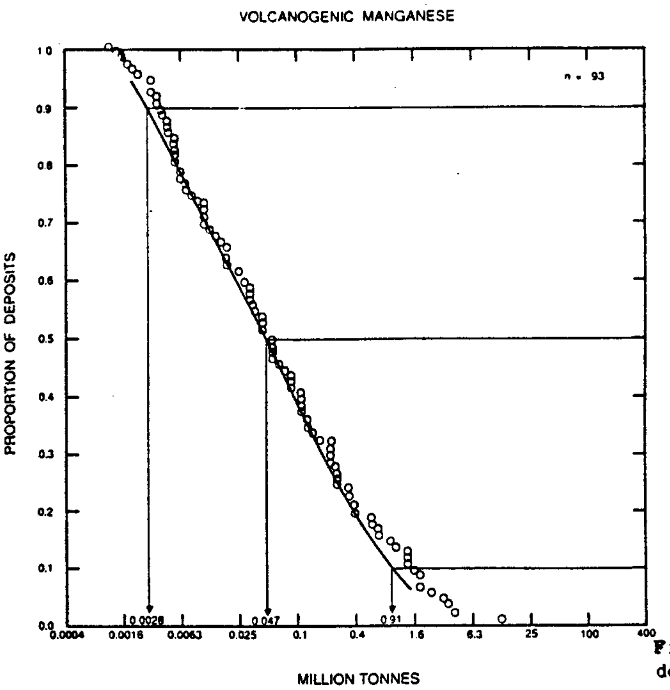

Figure 103. Tonnages of volcanogenic Mn deposits.

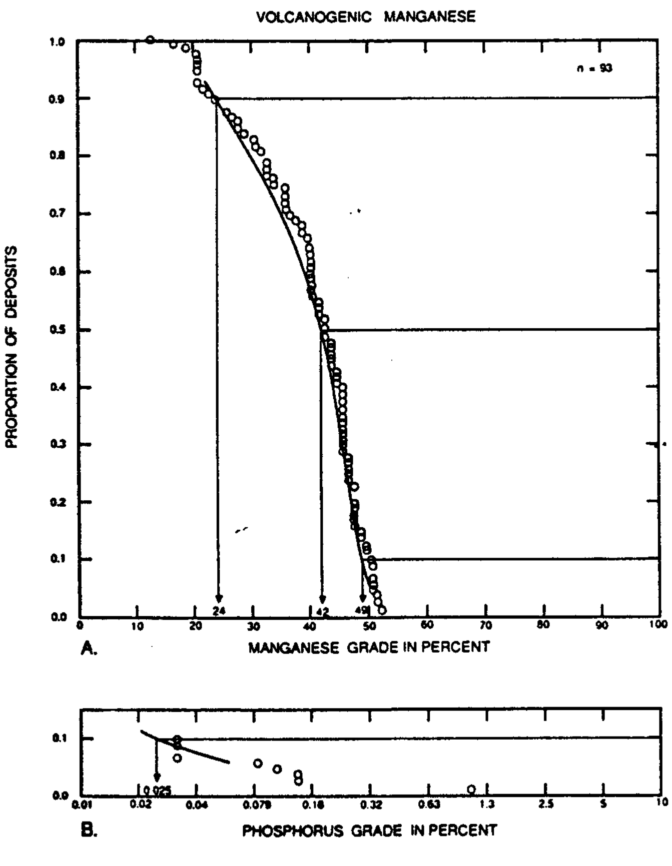

Figure 104. Metal grades of volcanogenic Mn deposits. A, Manganese. B, Phosphorus.

Figure 9. - Grade and tonnage diagrams for volcanogenic manganese deposits (16).

magnetometer survey of Chenega Island. Reconnaissance level studies in Prince William Sound should also be performed on the Peninsula to the north of Chenega Island from Port Nellie Juan to Jackpot Bay and along the west coast of Knight Island, east of Chenega Island. The investigations should focus on mapping and sampling of geologic environments and alteration styles favorable for manganese deposition,as defined at Chenega Island.

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